Experimental Study on Pervious Concrete by Varying Size and Shape of Aggregate

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Abstract**—** the paper deals with the laboratory results & study undertaken to determine the different shapes and size of aggregates on permeability and compressive strength of pervious concrete. Shape of aggregate is measured in terms of their angularity number. Angularity or absence of rounding of the particles of an aggregate is an important property because it affects the porosity, surface area in contact with each other in the matrix of ingredients and ease of handling of a mixture of aggregate and binder. It is seen that permeability of pervious concrete varies with function of angularity number of aggregates used and also strength is affected by replacement of cement with fly ash. The results of this study would lead to a better understanding of the manner in which aggregate gradation can be used to optimize a pervious concrete mixture depending on project or site-specific requirements.

Keywords—*pervious concrete, aggregate size and shape, flyash.*

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INTRODUCTION

Pervious cement is a kind of cement with high porosity. It is utilized for solid flatwork applications that permit water to go specifically through it, accordingly decreasing the overflow from a site and permitting groundwater energize. The high porosity is achieved by an exceedingly interconnected void substance. Ordinarily pervious cement has water to cementitious materials proportion (w/cm) of 0.26 to 0.40 with a void substance of 18 to 35%.

The blend is made out of cementitious materials, coarse total and water with next to zero fine totals. Expansion of a little measure of fine total will for the most part decrease the void substance and increment the quality, which might be attractive in specific circumstances. This material is touchy to changes in water content, so field modification of the new blend is typically vital. An excess of water will bring about glue channel down, and too little water can frustrate satisfactory curing of the solid and lead to surface disappointment. A legitimately proportioned blend gives the blend a wet-metallic appearance.

ENVIRONMENTAL EFFECT OF CEMENT USAGE

In 2003, the world's Portland bond creation achieved 1.9 billion tones. The most crowded nations on the earth, to be specific China and India, created 41.9% and 5.2% separately of the world's concrete yield. As the interest for solid builds, current Portland bond generation will be generously expanded. Since one tone of concrete generation discharges 0.93 tons of CO_2 into the air, bond creation contributes fundamentally to an Earth-wide temperature boost which prompts undesirable environmental change. Subsequently it is key for the solid business to know about the results of using ecologically threatening bond. Each exertion ought to be made to minimize the utilization of Portland bond in cement blends. In cement blends, 2 Portland concrete ought to be somewhat supplanted with an assortment of demonstrated supplementary cementitious materials, for example, common pozzolans, fly fiery debris and ground-granulated impact heater slag. Generous utilization of these cementitious materials will deliver naturally benevolent cement blends.

A. hy Do We Need Pervious Concrete?

A larger amount of rainwater ends up falling on impervious surfaces such as parking lots, driveways, sidewalks, and streets rather than soaking into the soil. This creates an imbalance in the natural ecosystem and leads to a host of problems including erosion, floods, ground water level depletion and pollution of rivers, lakes, and coastal waters as rainwater rushing across pavement surfaces picks up everything from oil and grease spills to de-icing salts and chemical fertilizers.

A basic answer for maintain a strategic distance from these issues is to quit developing impenetrable surfaces that square common water penetration into the dirt. Instead of

ISSN: 2321-8169
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building them with traditional cement or black-top, we ought to change to pervious concrete or permeable asphalt, a material that offers the inalienable strength and low life-cycle expenses of a run of the mill solid asphalt while holding storm water spillover and recharging nearby watershed frameworks. Rather than forestalling penetration of water into the dirt, pervious asphalt helps the procedure by catching water in a system of voids and permitting it to permeate into the basic soil. Much of the time, pervious cement roadways and parking garages can twofold as water maintenance structures, decreasing or disposing of the requirement for customary tempest water administration frameworks, for example, maintenance lakes and sewer tie-ins.

Pervious cement additionally actually channels water from precipitation or storm and can decrease poison loads going into streams, lakes and waterways. So thusly it helps in ground water energize.

It likewise decreases the awful effect of urbanization on trees. A pervious solid ground surface permits the exchange of water and air to attach frameworks permitting trees to prosper. For a given precipitation power, the measure of spillover from a past solid asphalt framework is controlled by the dirt penetration rate and the water stockpiling limit accessible in the past concrete and total sub base under the past cement. For the most part for a given arrangement of materials, the quality and invasion rate of pervious cement are an element of solid thickness. More prominent the thickness, higher is the quality and lower the penetration rate.

EXPERIMENTAL STUDY

The testing plan was devised to determine the shape characteristics of the aggregate, Los Angel's abrasion value, water absorption, specific gravity, unit weight, void content and angularity number of the collected aggregate sample from two different sources (Uran and Turbhe). Details of material, mix proportion, sample preparation and test method used is as follows:

A. Materials

Cement:

Portland pozzolana cement (Fly Ash based) procured from local suppliers was used in the experiments. Specific Gravity of the cement procured and used to carry out experiments was found in the range of 2.89-2.9. Various properties of cement are given in Table 1

TABLE I. PROPERTIES OF CEMENT

Particulars test	**Result values**	**Requirements of IS: 1489-1991 Part I**	
Standard consistency (%)	29-30	-	
Setting time (Minutes)			
a. Initial	165-175	30	Minimum
b. Final	215-230	600	Maximum
Compressive strength (N/mm2)			
a. 168 +/- 2 hr. (7 days)	41.0	22	Minimum
b. 672 +/- 4 hr. (28 days)	58.0-59.0	33	Minimum

A. ***Aggregates:***

To decide about the sizes of course aggregate to be used in preparation of pervious concrete mix, findings and reports of various researchers was referred. Schafer et al. (2006) reported that he coarse aggregate used in pervious concrete is typically single size rounded river gravel or a crushed stone. Tennis et al. (2004) has reported that to manufacture pervious concrete, course aggregate is kept to a narrow gradation. Coarse aggregate having 9.5 mm top size has been used extensively for parking lot and pedestrian application. He also reported that typically higher strengths are achieved with rounded aggregates, although angular aggregates generally are suitable. On the basis of these recommendations and other referred literature for this study, three different types of course aggregates having different shape characteristics were collected from two different local stone crushing plants. Based on their shape characteristics the aggregates were classified as flaky, angular and irregular as described in IS: 2386 (Part I)-1963. The aggregate test samples collected were separated into single size fractions using IS standard sieves. Details of the pair of sieves used, size identification of the aggregate retained between pair of sieves (square mesh) and their properties are given in Table 2.a and 2.b

TABLE II. (A) PROPERTIES OF AGGREGATE SAMPLES USED IN EXPERIMENT.

TABLE II.(B) PROPERTIES OF AGGREGATE SAMPLES USED IN EXPERIMENT.

Aggregate Type (Sample)	**Aggregate as retained between the pair of Sieves**	**Compacted Unit Weight (kg/m3)**	**Voids (%)**	**Average Angularity Number**
F (Flaky)	20mm and 16 mm	1472	46.55	13
	16mm and 12.5 mm	1463	46.99	
	12.5 mm and 10 mm	1454	47.32	
A (Angular)	20mm and 16 mm	1595	42.14	10
	16mm and 12.5 mm	1582	42.89	
	12.5 mm and 10 mm	1569	43.36	
I (Irregular)	20mm and 16 mm	1680	39.32	7
	16mm and 12.5 mm	1672	39.69	
	12.5 mm and 10 mm	1663	39.96	

S. No	**Shape Characteristics of the Aggregate**	**Flakiness Index (%)**	**Aggregate Type**	**Los Angels Abrasion-on Value (%)**	**Mean Water Absorption (%)**	**Specific Gravity**
1	Material having small thickness relative to the other two dimensions	40	F (Flaky)	22	0.81	2.76
2	Possessing well defined edges formed at the intersection of roughly planner faces	11	A (Angular)	17	0.78	2.77
3	Partly shaped by attrition and having rounded edges	6	I (Irregular)	11	0.62	2.77

A. Water:

Potable water was used for preparation of mix and curing of concrete sample. As the scope of the study is limited to find out the effect of angularity number of aggregate used in pervious concrete, chemical admixtures is not used in the study.

B. Mix Proportions:

Three types and three sizes of aggregates as explained in Table 2 (a) and 2 (b) were used to conduct the study. Mixes with 0.39, 0.42 and 0.45 W/C were prepared keeping aggregate cement ratio 4.0 for this set of study.

C. Test methods:

Various engineering and physical properties of the aggregate sample used in the study, like flakiness index, angularity number, specific gravity, water absorption; bulk density, void contents and Los Angels Abrasion Value were determined using the procedure as explained in IS: 2386 (Part I)- 1963, IS:
2386 (Part III) - 1963 and in IS: 2386 (Part IV) - 1963 respectively. The test mixes were prepared using a machine mixer. Each time the mix preparation was started following an initial butter batch in the mixer having the same proportions as the desired mix. To determine permeability of the pervious concrete mixes, cylinders of 100 mm diameter and 150 mm long were casted. Compaction method used was same as described in IS codes to prepare cube samples to determine compressive strength. The samples were cured for 7 days and tested there after using constant head permeameter designed and assembled in the laboratory for this purpose. A schematic diagram of the constant head permeameter used in the research is given in Figure 1. The outflow pipe in the inlet chamber of the permeameter was so

placed that a constant water head of 50 mm is maintained above the top of sample. Amount of water percolated through the sample within known time interval (60 seconds) were recorded to determine the permeability in mm/hour.

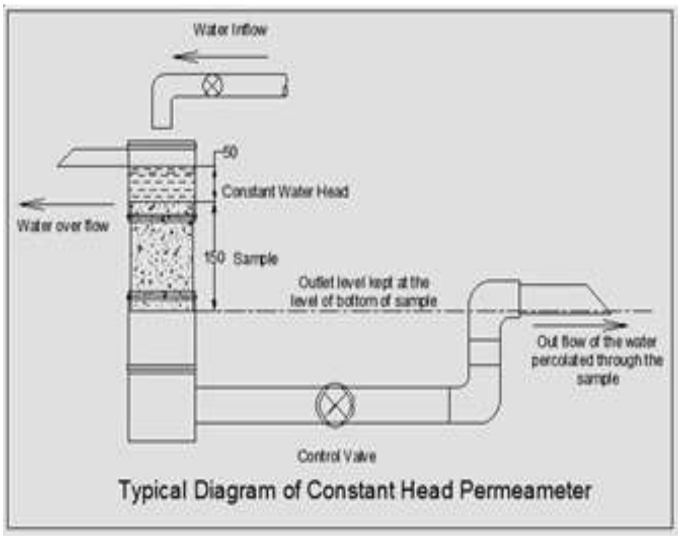

Fig. 1: Typical diagram of Constant head Permeameter used to determine permeability of pervious concrete specimens

To determine compressive strength, cubes of different mixes were casted and tested for 3, 14 and 28 days.
On the basis of the results obtained, effect of angularity number of aggregate, size of aggregate, W/C ratio on permeability and compressive strength of the pervious concrete mixes were evaluated and presented in form of tables and graphs.

TEST RESULT AND DISCUSSION

Results of the study performed to evaluate the influence of the shape of aggregate measured in terms of its angularity number on permeability and compressive strength of pervious concrete is presented in Table 3-4.

TABLE II. COMPRESSIVE STRENGTH OF PERVIOUS CONCRETE PREPARED USING DIFFERENT SIZE AND W/C RATIO.

W/C RATIO ⇨ ⇩ SIZE	**Compressive strength for "0.39" w/c ratio (N/mm2)**	**Compressive strength for "0.42" w/c ratio (N/mm2)**	**Compressive strength for "0.45" w/c ratio (N/mm2)**
SOURCE 1 - 10mm	11.95	12.23	11.12
16mm	10.95	11.25	11.06
20mm	10.10	9.84	10.22
SOURCE 2 - 10mm	11.45	12.05	11.56
16mm	10.54	11.00	11.14
20mm	10.02	10.41	10.07

TABLE III. PERMEABILITY AND COMPRESSIVE STRENGTH OF PERVIOUS CONCRETE PREPARED USING AGGREGATE OF DIFFERENT ANGULARITY NUMBER, SIZE AND WITH DIFFERENT W/C RATIO

MIX- ID	**PERMEABILITY mm/hr**	**COMPRESSIVE STRENGTH @ 28 days N/mm2**
F-20-0.39	6423	8.95
F-16-0.39	5914	9.12
F-10-0.39	4605	10.12
F-20-0.42	4112	9.10
F-16-0.42	3424	9.25
F-10-0.42	2470	11.55
F-20-0.45	3069	9.94
F-16-0.45	2713	10.15
F-10-0.45	2442	10.95
A-20-0.39	3269	10.22
A-16-0.39	2923	10.59
A-10-0.39	2314	12.23
A-20-0.42	2414	10.11
A-16-0.42	2069	11.50
A-10-0.42	1572	12.00
A-20-0.45	532	10.05
A-16-0.45	421	11.26
A-10-0.45	236	11.29
I-20-0.39	232	9.15
I-16-0.39	194	10.24
I-10-0.39	152	10.95
I-20-0.42	54	10.08
I-16-0.42	66	10.54
I-10-0.42	104	10.99
I-20-0.45	36	9.56
I-16-0.45	40	10.05
I-10-0.45	76	10.06

**Note*
F – Flaky
A- Angular
I- Irregular

The values are also plotted in the form of graphs between w/c ratio and permeability and also w/c ratio and compressive strength for various aggregate types and sizes and presented as Figure 2- 6. It is well demonstrated from the graphs that pervious concrete mixes prepared using aggregates having higher angularity number i.e. flaky aggregate taken in the study demonstrating more permeability in comparison to the mixes prepared using aggregates of lower angularity number. It is also clearly visible that the permeability of pervious concrete varies as a function of W/C ratio and aggregate size. In fact the W/C ratio influences the total porosity of the pervious concrete section. Increase in W/C ratio leads to reduced porosity of the mix, which in turn leads to reduced permeability of the pervious concrete mix. Figures also demonstrate that for all types of aggregates, pervious concrete mix prepared using smaller size of aggregates produced less permeability in comparison to the mix produced with larger size aggregate. The explanation of these phenomena may be that the flow of water from pervious concrete section is more influenced by the sizes of pores rather than total porosity in the concrete section. Pervious concrete prepared using larger size particles produced pores larger in size, which causes higher permeability through the section.

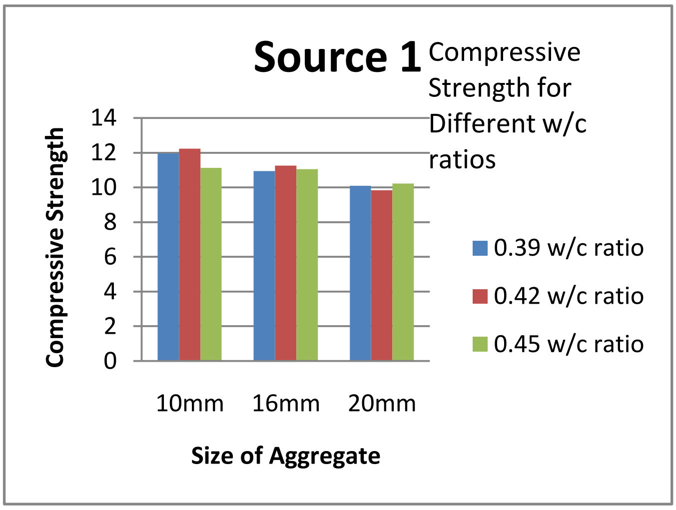

Fig.2 Compressive Strength For Different Size Of Aggregates And W/C Ratio

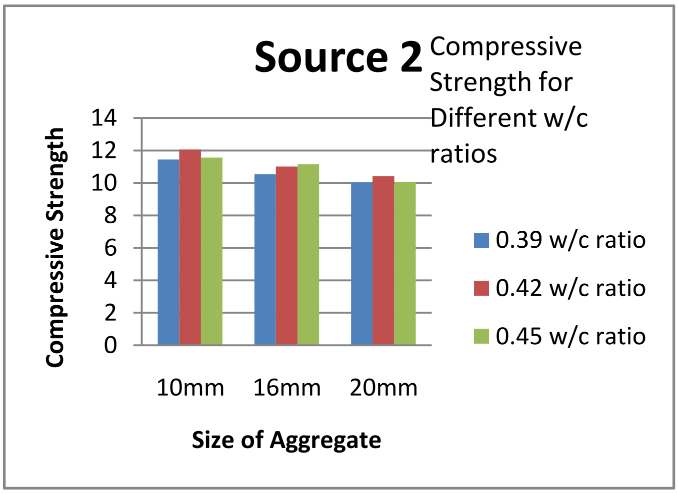

Fig.3 Compressive Strength For Different Size Of Aggregates And W/C Ratio

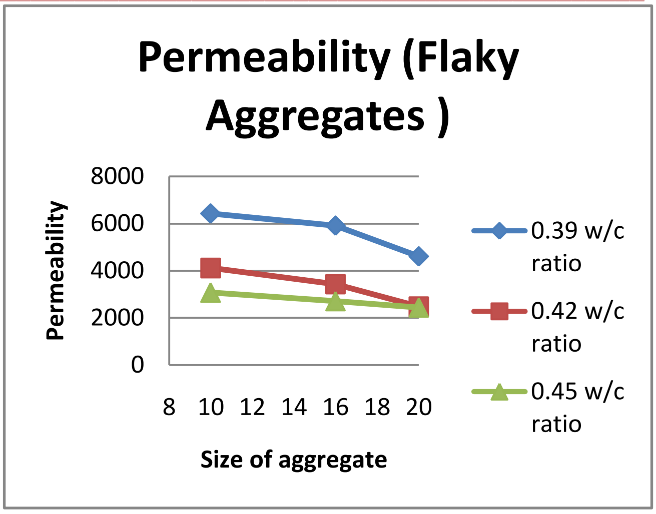

Fig.4 Permeability for Different Size of Aggregate And Different W/C Ratios

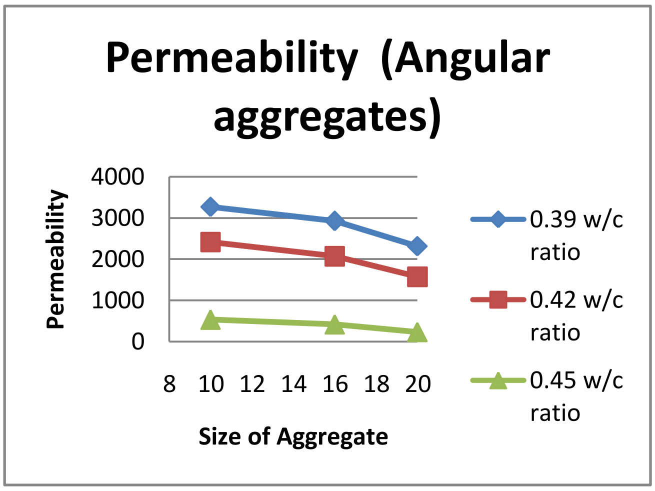

Fig.5 Permeability for Different Size of Aggregate And Different W/C Ratios

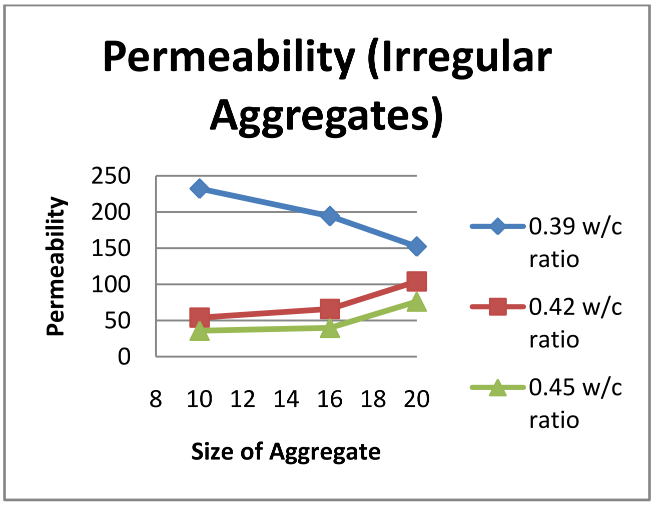

Fig.6 Permeability for Different Size of Aggregate And Different W/C Ratios

CONCLUSION

For the three types of aggregates tested having angularity number 13, 10 and 7, aggregate with higher angularity number produced more permeability. For a given type and size of aggregate, there is an optimum W/C ratio which produced balanced mix. Less than this optimum ratio have produce a mix having dull surface appearance leading to unsatisfactory performance of the pervious concrete, whereas more W/C ratio may cause the problem of paste draw down resulting to chocking of the pores at bottom leading to the functional failure of the pervious concrete. In light of all these findings it is of utmost importance to precisely analyze the given aggregate size and type for optimum W/C ration to avoid paste draw down which hamper the permeability property of pervious concrete to perform its intended function. Permeability of pervious concrete varies as a function of W/C ratio and size of aggregate. For all types of aggregates, permeability of pervious concrete is recorded less for smaller size of aggregate. Rate of reduction of permeability with increase in W/C ratio is more for pervious concrete having aggregate with

ACKNOWLEDGMENT

The authors wish to thank Sardar Patel College of Engineering for providing funding to the research work under TEQIP.

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